MINERALS AND ENERGY DIVISION
DEPARTMENT OF NATURAL RESOURCES
AND ENERGY
NEW BRUNSWICK

Open File Report 88-10

PROCESS STUDIES GROUP

QUARTERLY PROGRESS REPORT:

"REVIEW OF ACTIVITIES - OPEN HOUSE 1987"

by

J. Dean Thibault

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Entente Canada-Nouveau-Brunswick L'Exploitation Minérale

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PROGRESS STUDIES GROUP

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PROCESS STUDIES GROUP

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QUARTERLY PROGRESS REPORT

"Review of Activities - Open House 1987"

MINERAL DEVELOPMENT

NATURAL RESOURCES AND ENERGY

SIX MONTHS ENDED

SEPTEMBER 30, 1987

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CONTENTS

MINERAL PROCESSING INVESTIGATIONS PROGRAM (MPIP) page 4

MINERAL INVESTMENT STIMULATION PROGRAM (MISP) page 25

PROCESS STUDIES GROUP

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ESTABLISHED 1986

The objective of interim reports is to provide project status on mineral processing studies being administered by Mineral Development and to assure a coordination of development among industry, government, universities, research and development.

This interim report was prepared for open house activities and will contain short discussions on various project findings since last November. Detailed reports on projects are being made available through provincial publications (open file reports).

*NOTE: MPIP and MISP are funded by the Federal Government under the Mineral Development Agreement.

**PART TIME ASSISTANCE

As part of characterizing the separation and upgrading of various ores, the Process Studies Group has been looking at the various methods being developed by various research institutions on flowsheet design. The projects being carried out under the Mineral Processing Investigations Program have used various methods to review processing options of ores.

In the development of a gravity separation circuit for Mount Pleasant ores, grade versus recovery curves were graphically analysed using a method prepared by J. Finch of McGill University, called, "Analysis of Separation".[1] The graphical solution method was used to determine the optimum grades of rougher, scavenger and cleaner unit operations from gravity tests done on a Mozley Mineral Separator.

It has been found that the graphical method is a good method to optimize the performance of a separation circuit, however, further development of this method will be required to design flowsheets. Theoretical data indicates the optimum separation that can be achieved, based on physical properties of the ore, and does not consider the operating or mechanical efficiency of separation equipment. Hence, this method can be used to determine the ore separation characteristics and determine the efficiency of separation equipment operation.

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[1] J. Finch, "Analysis of Separation ", Short Course on Mineral Processing Systems, McGill University, Montreal, Quebec, January, 1986.

With respect to flowsheet development of gravity circuits, an approximation of the grade and recovery can be made with bench scale testwork. In order to fully develop a flowsheet, especially on tungsten separation from Mount Pleasant ores, high tonnages and the use of a pilot plant will be required.

Similarly, in the development of a flowsheet for bulk sulfide flotation of complex sulfides, the methods being developed by G. Barbery, of Laval University, have been aimed at using laboratory flotation kinetic studies for commercial scaleup. A computer program called CALFLOT,[(2)] is a design and simulation program using various lab flotation parameters plus scaleup factors. The data is entered in this program from lab tests and any data not known is then drawn from a data bank. The program will simulate a complete circuit, including cell flows, cell size, recoveries and grades for up to two flotation species.

One may question the use of flowsheet development techniques and the net benefits to industry, in an area which may be considered somewhat academic to a developer or an operation. The use of these bench-scale techniques and computer simulation provides information on the ore (on how to achieve a most efficient separation and upgrading of the ore) and will provide a good understanding of a new generation of process control, called, "Expert Systems" in addition to the design of optimum processing facilities.

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(2)G. Barbery, M. Bourassa, A. Maachar, "Design and Installation of Concentration and Dewatering Circuits", Mular & Jargeuse, AIME, New York, 1986.

For the last two years, computers used in mineral and chemical processing have moved from simulation of processes to commercial applications of mathematics solving process evaluation and optimization tasks. Computer simulation is used for specification and circuit design where model predictions are used to optimize equipment size and flowrates of process streams. Development of expert systems is defined as "state-of-the-art" by combining simulation with adaptive process control. An estimator combines model predictions with actual process variable measurements to define the state of the process. An optimizer selects the set of control actions to meet a certain objective.

The Process Studies Group recognized that optimization of resource development is gradually becoming a high technological industry and the problem with modern control theory is that the applications are not clearly understood, where a user's knowledge of mathematics, processing technology, computer software and hardware, along with process control theory is essential. In order for automation in mineral processing to be successful, a strong knowledge of ore separation characteristics is required, where a system has to understand "what happens if . . . "

The single, most important factor on economic return is the availability of suitable technology for the development and operation of a competitive mineral industry. In addition to the elements of modern control theory (i.e., all the "in's" and "out's" of expert systems), industrial and developmental personnel require the knowledge of "ore processing".

Chemical processing is expected to take an increased role for the development of complex ores where physical methods may be used to upgrade deposits to remove readily separable minerals and improve on processing economics. Hence, a combination of physical and chemical techniques are to be integrated into plant circuits to improve on metal extraction. It can therefore be expected that a linking of disciplines is required for competitive processing rather than personnel trained in either/or mineral processing and extractive metallurgy. An overall knowledge of ore processing and ore separation characteristics is required in order for developments in automation and process technology to have a productive impact on the growth of our mineral industry.

Mineral Processing Investigations Program

The various projects being administered by the Process Studies Group under the Mineral Processing Investigation Program include flowsheet development and/or optimization through "simulation" and "ore processing" analysis techniques. Various process options that are existing or emerging technology are investigated to establish the economic as well as technical feasibility on New Brunswick mineral resources. A major aspect of mineral economics is the technological change in mineral extraction or the development of alternative or new technologies. In many cases, research (leading edge of technology) has been involved with merely technological considerations, rather than economic feasibility, which may be area (location) specific. As part of the investigations carried out by the Process Studies Group, it is our mandate to identify areas requiring further development, based on technical and economic limitations of New Brunswick mineral resources.

Based on the findings of investigations carried out to date, the following generalized concepts have been identified as areas which require further research. These concepts are presently limiting the development and optimization of New Brunswick mineral resources and are briefly discussed under each project heading.

* Optimization of grinding circuit and evaluation of regrind on antimony sulfide flotation circuit in order to recover fine unliberated stibnite.

* Technology development for the production of antimony oxide from antimony sulfide concentrates, making use of chloride hydrometallurgical systems.

* Extraction of gold from refractory gold ores using technology to avoid arsenic disposal, possibly by bio-technology.

* Recovery of cyanide from effluents as an alternative to cyanide distruction where high copper-gold ores result in environmental problems.

* Recovery of phosphate (for sulfate and/or nitrate fertilizers) and yttrium-rare earths from igneous apatite ores.

* Recovery of titanium from ilmenite-magnetite ores, using benefication techniques to produce ilmenite concentrates.

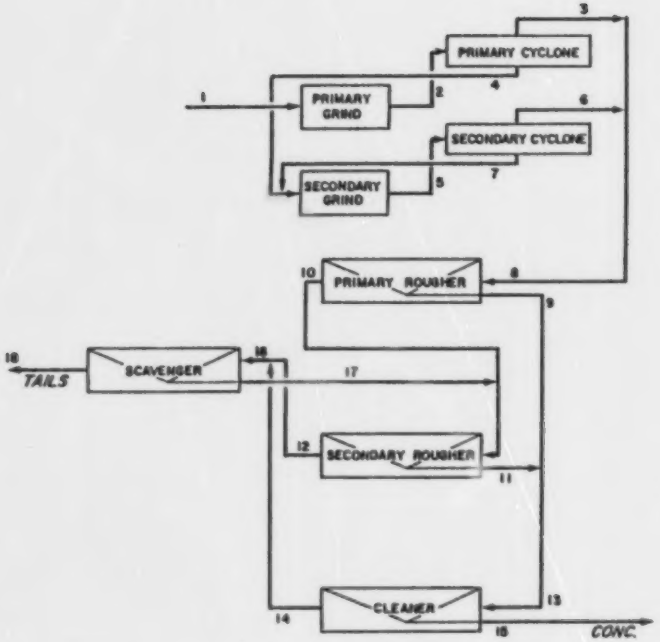
* Establishing optimum production methods of magnesium oxide from dolomite ores and sea water.

* Optimum conditions for the production of bulk sulfide concentrates from complex sulfide ores as a concept for a custom mill using column flotation to improve on selectivity.

Antimony Processing

Two studies have been completed and final reports are presently in the writing phase. The first study dealt with the optimization of metal recovery from the Durham concentrator, where the limitations to metal recovery was to be identified. A second study dealt with a literature search and an evaluation of various technologies to produce antimony oxide and/or metal from sulfide concentrates.

The overall analysis of the flotation circuit (figure 1) shows a recovery limitation in the +75u and -25u size fractions. The variation of flowsheet streams in the float circuit did not improve on the overall grade and recovery shown in figure 2. The results of mineralogical analysis indicate that a major loss of antimony is due to unliberated stibnite in the +25u fraction and the loss of -25u antimony may be partially due to liberation of stibnite and slow flotation of fines. The photographs shown in figure 3 illustrate the loss of antimony as fine specs on quartz particles.



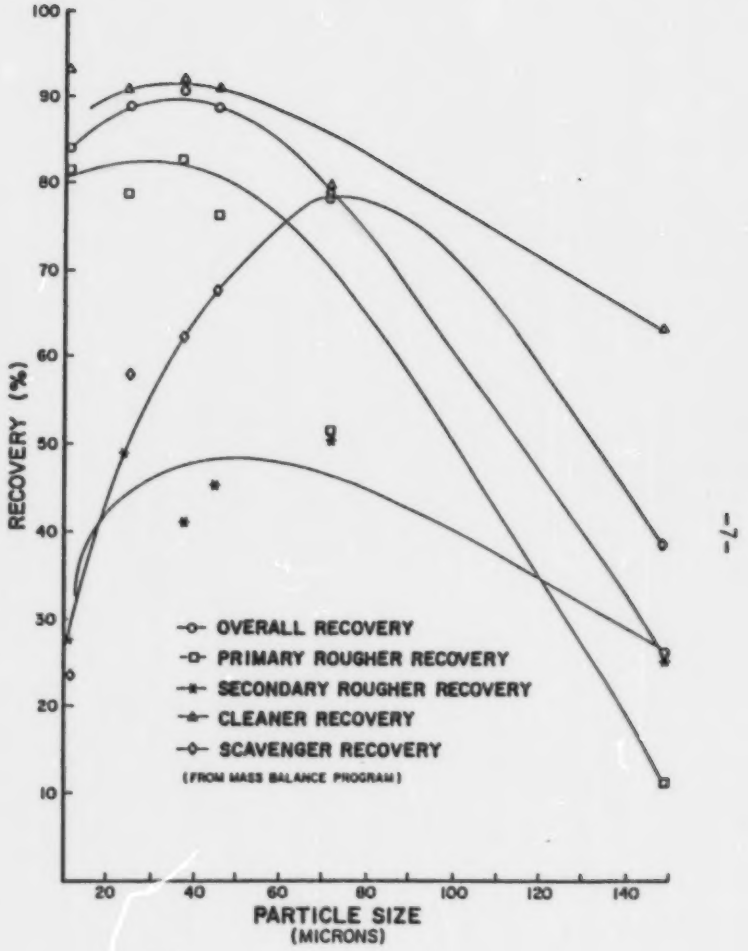


FIGURE 1: Operating flowsheet for testing at the Durham antimony concentrator. Recovery versus particle size is represented for each unit operation using Metbal mass balance program.

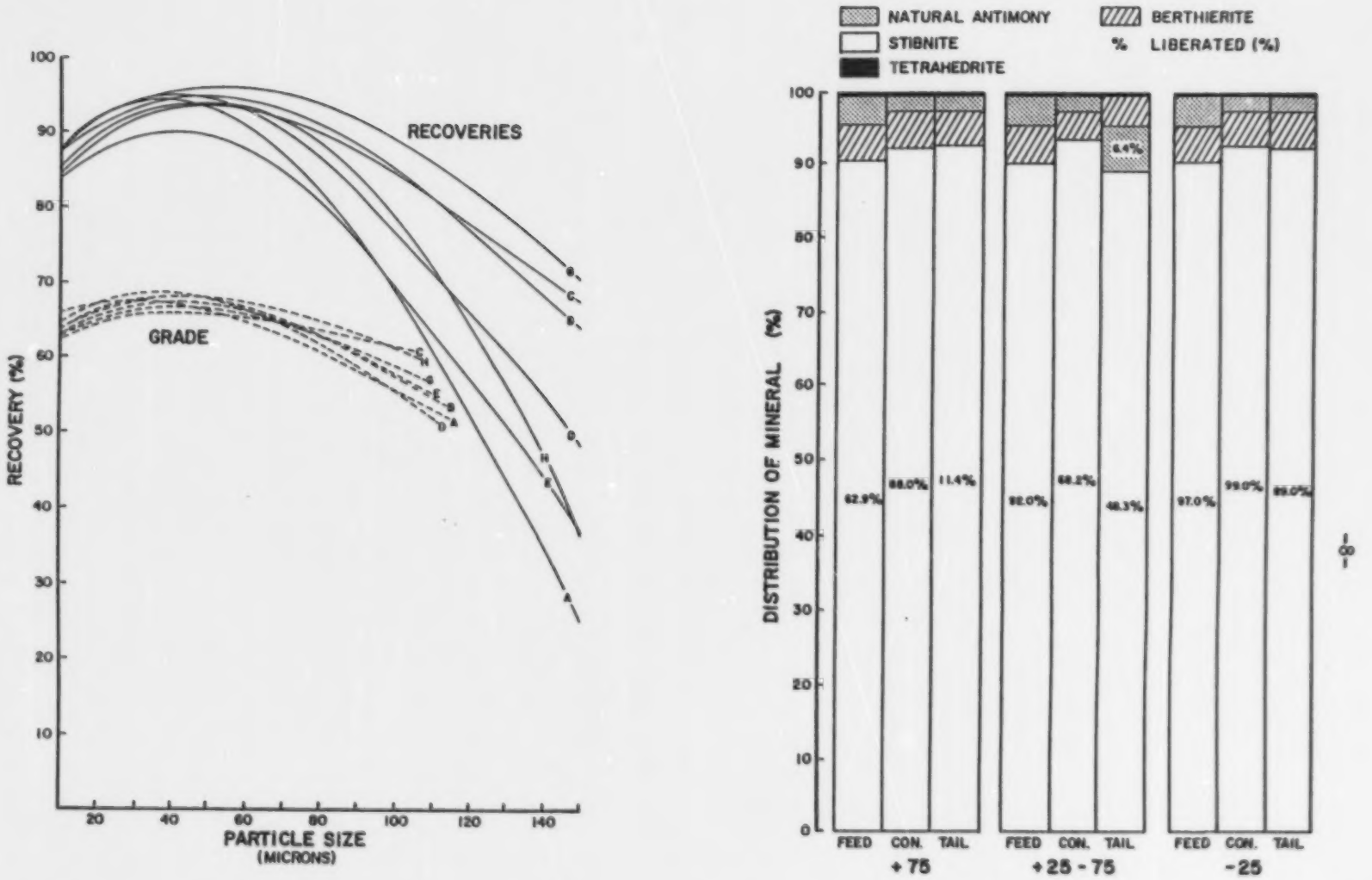


FIGURE 2: Result of grade and recoveries using various configurations of flotation flowsheet. Mineralogy done on various size fractions of feed, concentrate, and tailings.

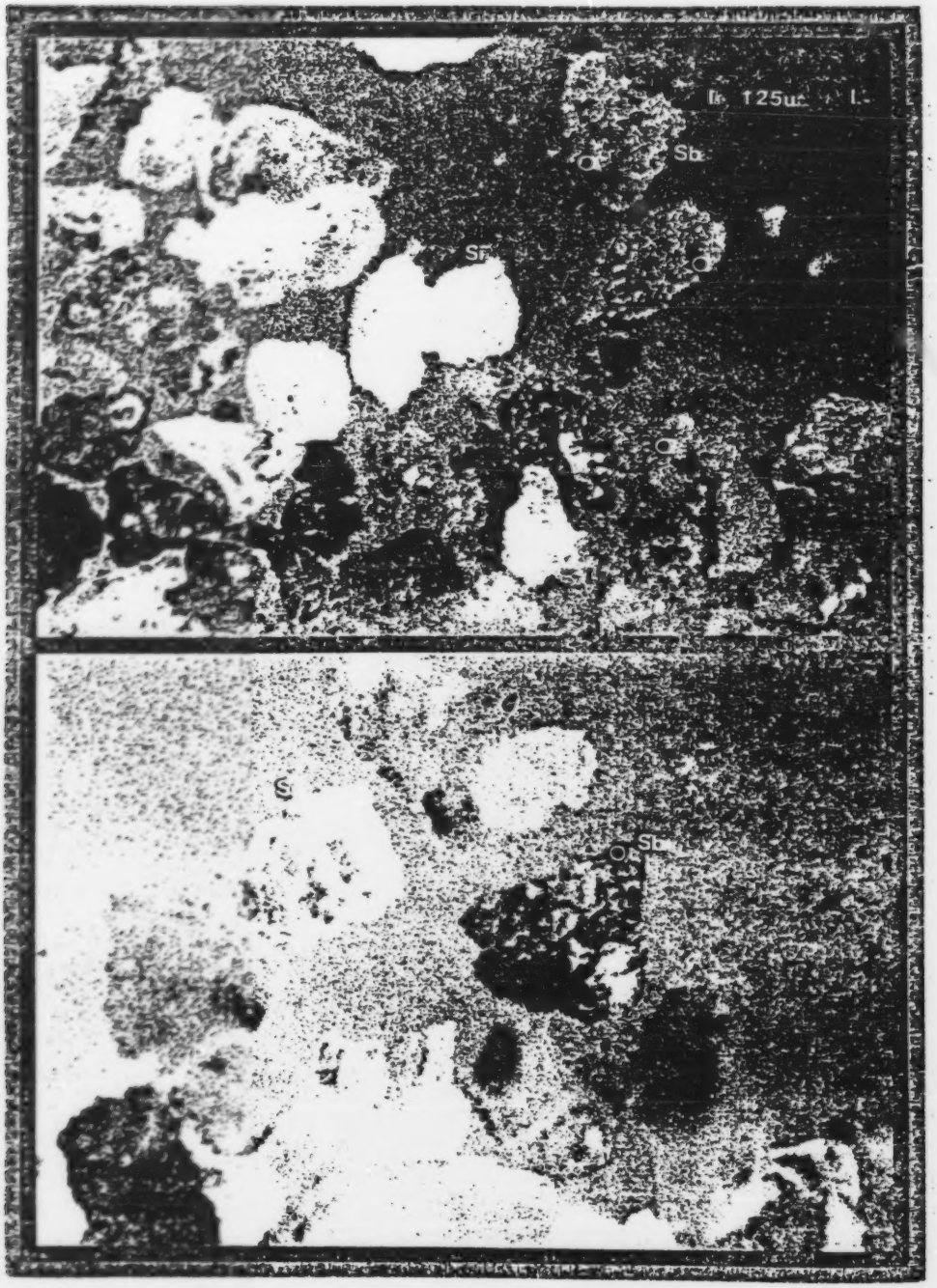


FIGURE 3: Photographs of natural particles from tailing of Durham concentrator, showing the salting of antimony mineralization on quartz particles.

Various technologies, to treat stibnite (Sb_2S_3) concentrates, were reviewed as a concept for an antimony products plant. The price of metal has favoured the production of antimony oxide, in addition to high processing costs to produce metal. Rotary kiln methods, as shown in figure 4, have been recognized as existing technology to produce crude oxide, having an operating cost $0.08 to $0.15/lb oxide. The major limitation with pyrometallurgical installations is the low recoveries due to antimony glass formation and sulfur oxide emissions. High temperature chloride systems have been identified as emerging technology to avoid operating problems with oxidation. The potential for low temperature chloride systems was bench-tested where further developments may overcome technical limitations. Major operating costs of chloride systems have been identified as chlorine reagent costs. In order to favour oxide production versus the sale of concentrate, figure 5 illustrates that (at today's commodity prices) overall production of oxide should not exceed $0.15(U.S.)/lb oxide.

Leachability of Gold Ores

Various studies have been completed on recovery of gold from various ores of New Brunswick, and a interim project report has been issued. Results have indicated that some of New Brunswick Gold deposits contain refractory gold, which is non-leachable.

Rolls tests done on Cape Spencer ores have demonstrated that the gold is about 90-95% recoverable using 1.5-3Kg NaCN/tonne ore. Heap leach tests

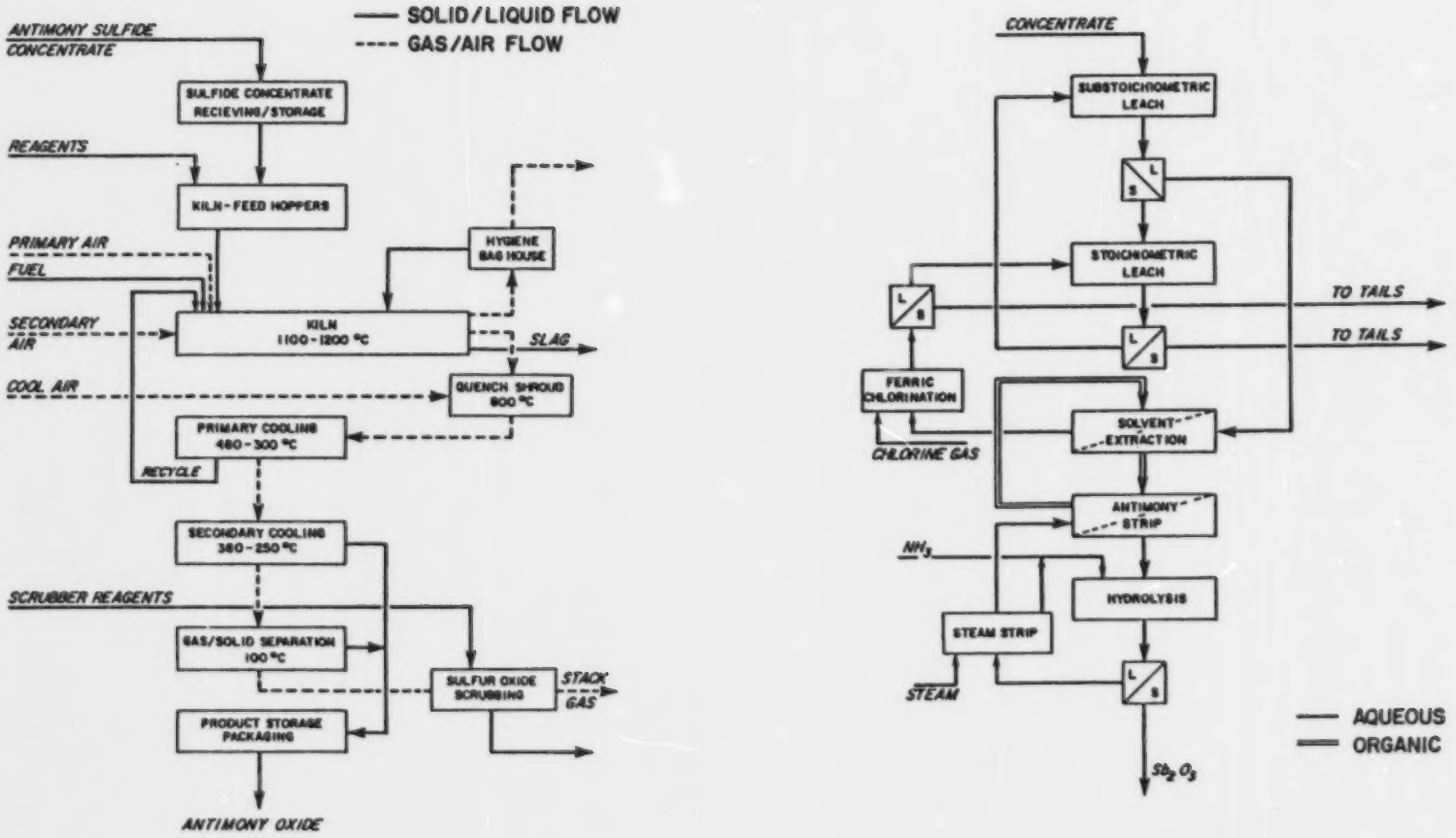


FIGURE 4: Rotary kiln methods versus leading edge technology of low temperature chloride systems.

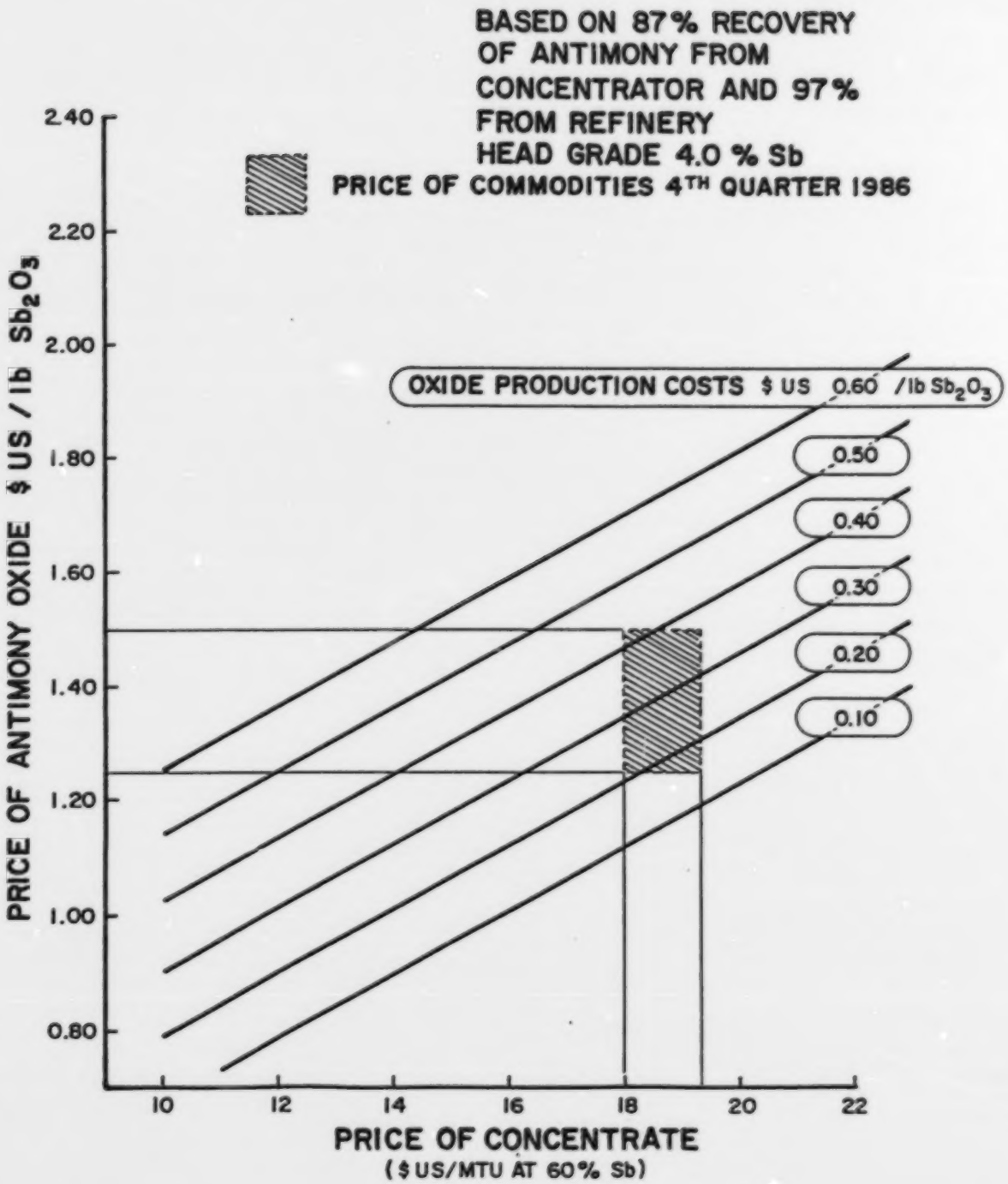


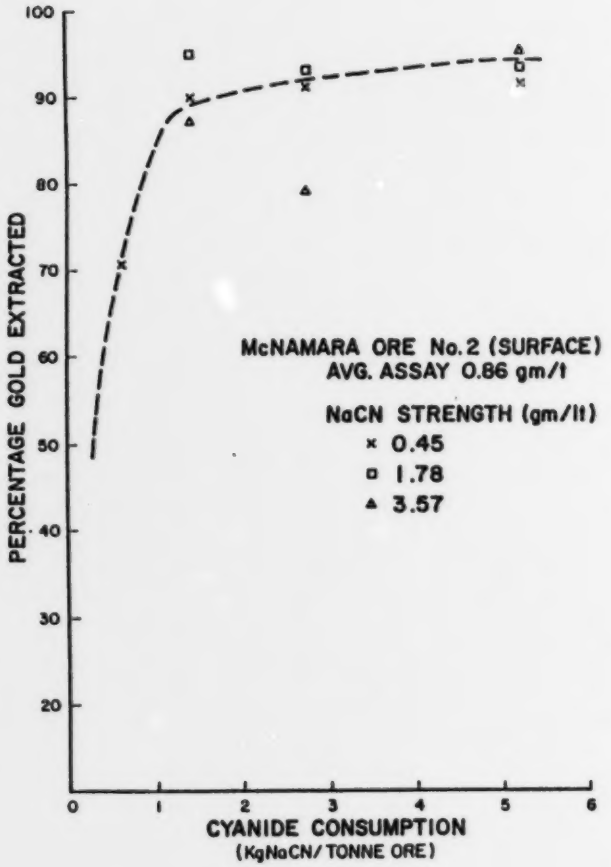
FIGURE 5: Operating cost analysis of oxide production. Each line represents a break even point.

have demonstrated that the ore is leachable at 1/4-1/2" crush, where 60% of the gold was recovered in 35 days and levels of copper increase with time as shown in figure 6. Cost analysis of a 10,000 tonne heap leach, with 70% recovery of gold, indicates that grades of 0.86gm/tonne ore are required to break even (based on a 20% ROI and gold values of $540(CDN)/oz). Higher tonnages will lower operating costs. This cost analysis has been used to establish a baseline for feasible grades for heap leach.

Various gold deposits identified at Alcidia (Bathurst Area) and at Lake George have been found to be refractory, based on limited extraction of gold using sodium cyanide. Mineralogy on these refractory ores has indicated that gold has occurred mainly in microfractures of arsenopyrite, as shown in figure 8. Work has been done to upgrade the arsenopyrite to favour the economic feasibility of roast-leach processing methods. Gravity upgrading as shown in figure 7 was found not to be as affective as flotation, where a single float test produced a concentrate containing 16.3gm Au/t with a gold recovery of 91%. Roast-leach extraction tests done on flotation concentrates extracted 25% of gold, indicating that further development is required on refractory gold ores.

Extraction of Specialty Metals

The driving force for the development of specialty metals in New Brunswick comes from the high growth marketing potential of these metals, as indicated by Kline in figure 9. Rather than dealing with the



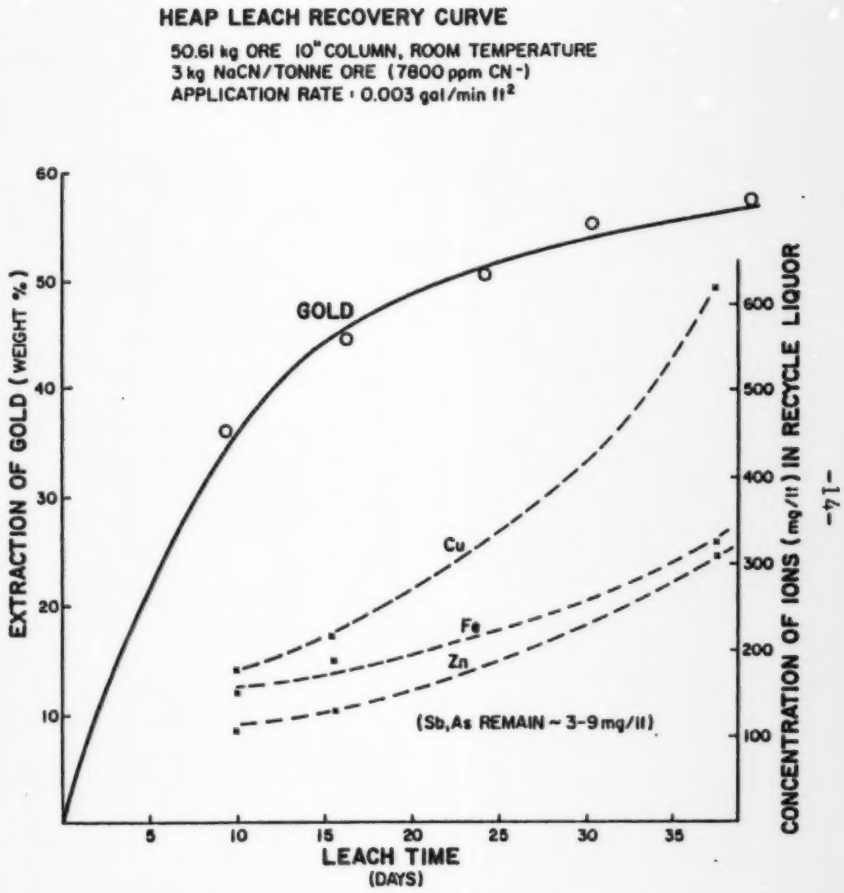


FIGURE 6: Rolls tests and heap leach tests done on Cape Spencer gold deposit (surface ore). Gold recovered by carbon columns in heap leach test unit.

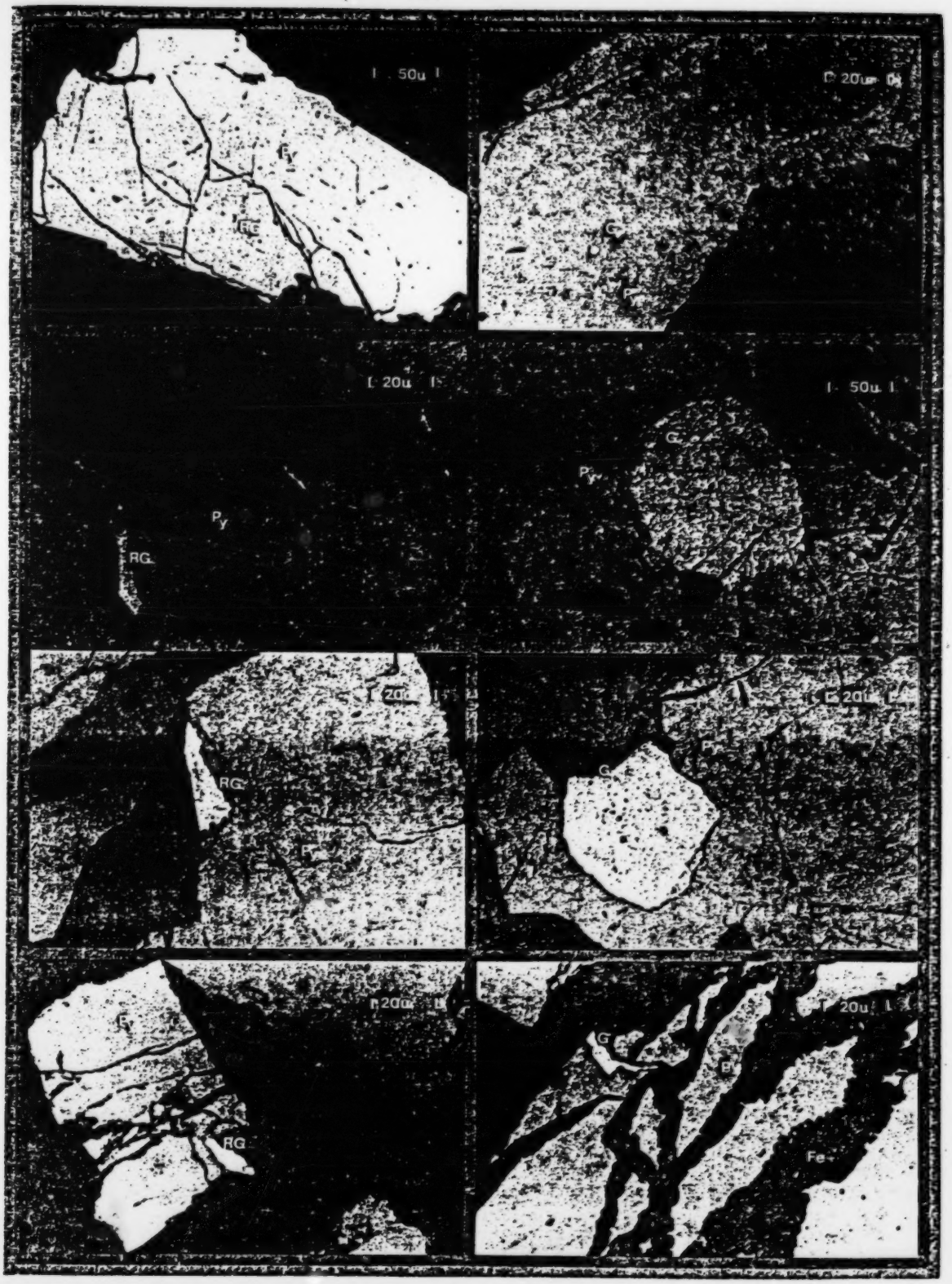
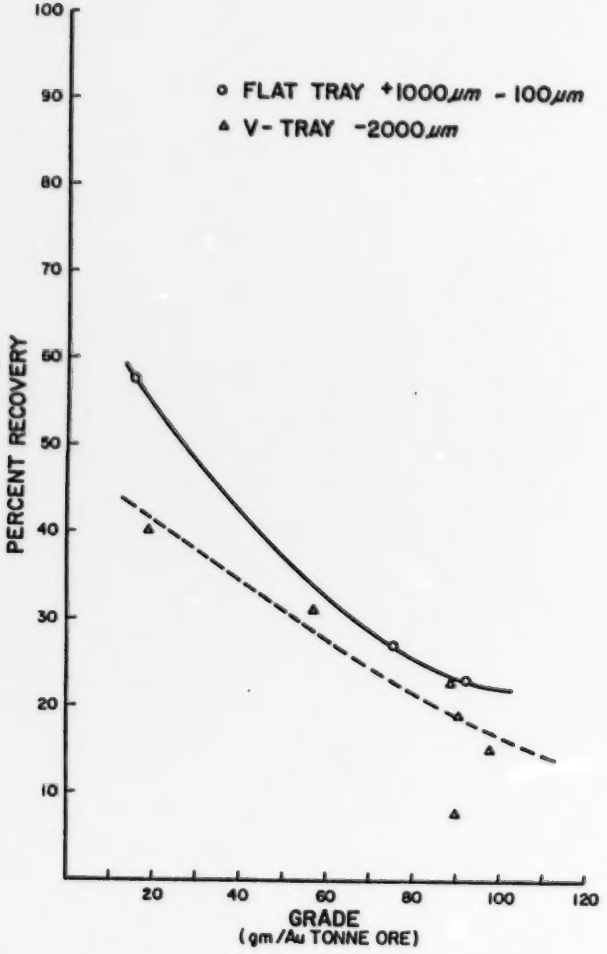


FIGURE 7: Left-hand side: native gold found to be refractory which occurs within and adjacent to arsenopyrite crystals.
Right-hand side: leachable gold occuring in pyrite and predominantly iron oxyhydroxides.



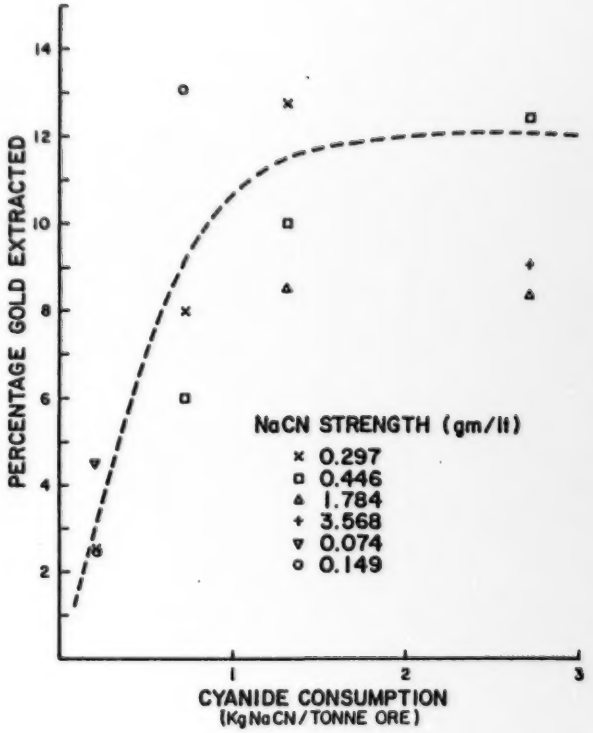
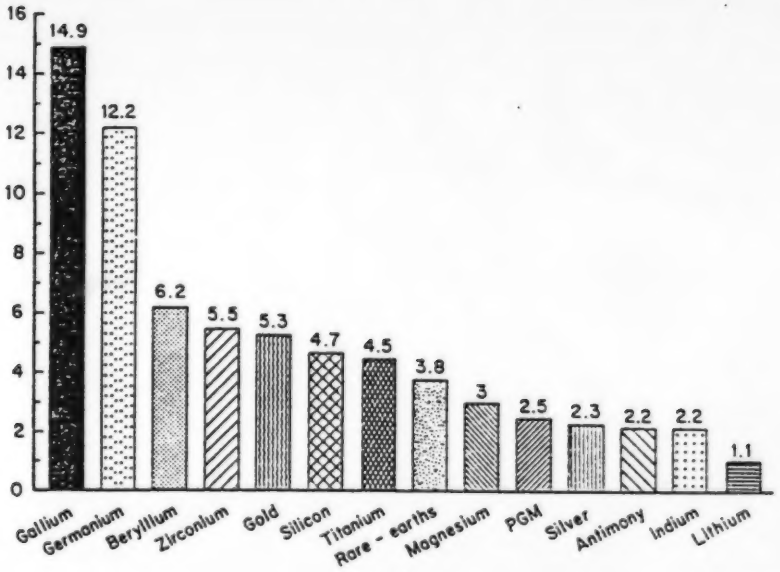


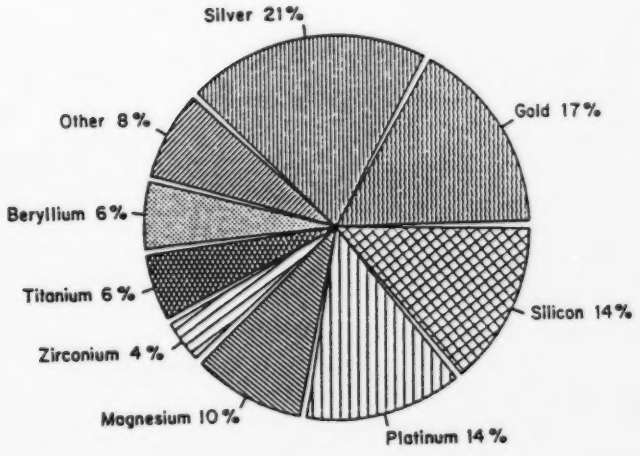
FIGURE 8: Gravity upgrading of refractory gold ores, where leach tests, using sodium cyanide, have resulted in low extractions.

U.S. OUTLOOK FOR SPECIALTY METALS BY METALS
Percent per year, 1985 - 1990



Kline & Company, Inc.

U.S. MARKET FOR SPECIALTY METALS BY METAL, 1985
Percent of $ 3.5 Billion Total



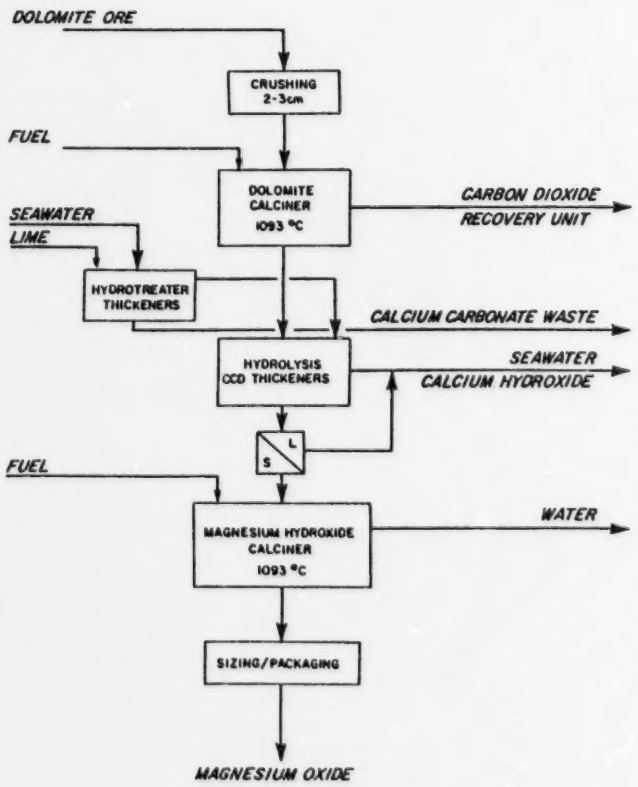
Kline & Company, Inc.

FIGURE 9: Growth of various metals used in electronics, ceramics, alloys, and high purity chemicals generating $35(U.S.) Billion in sales.

development of an orebody with known metal content, we are seeking resources within the province that contain high growth metals such as magnesium, rare earths (yttrium and the lanthanide metals), titanium, zirconium, beryllium, germanium, and gallium. One of the major problems with the development of high growth metals is that various companies, who are aware of the growth potential, are going into production and influencing demand. Providing information to industry on specialty metal locations and extraction characteristics increase the potential for development in New Brunswick.

In view of development potentials for magnesium, various dolomite deposits have been identified with quantified tonnages. A flowsheet for the production of synthetic magnesium oxide has been identified for a 500t/day operation, as shown in figure 10. About 50% of the magnesium oxide produced is recovered from magnesium in sea water. It has been estimated that this operation is capable of generating approximately $27 million in annual sales where major operating costs will be associated with fuel for kilns. The overall feasibility of this operation is being reviewed.

Rare earths have been found at economic levels in the Mount Pleasant ores and the Benjamen River apatite occurance. Mineralogy of rare earth association in the Mount Pleasant ores has indicated that cesium and yttrium occur in yttrofluorite, cesium $\pm$ yttrium fluorocarbonates and fluorophosphates, which are associated with fluorite. Further work is being carried out on the possible recovery of rare earths from both ores. A conceptual development scheme for igneous-apatite ores, as shown in figure 10, will be bench-tested to determine the overall development feasibility of this deposit.



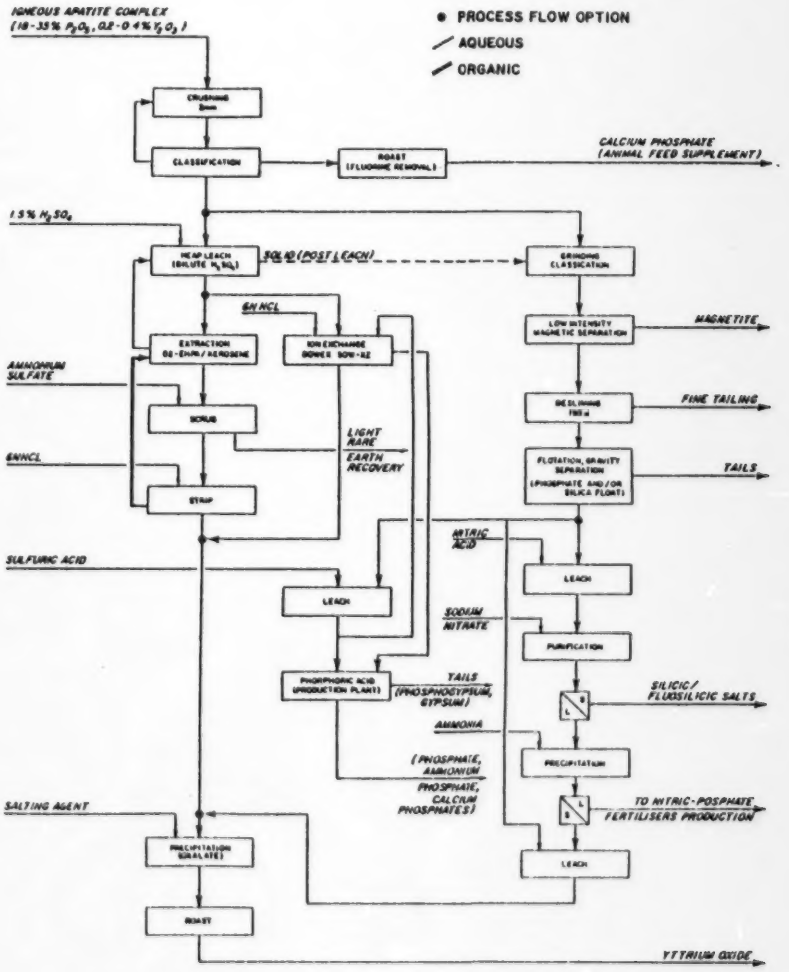


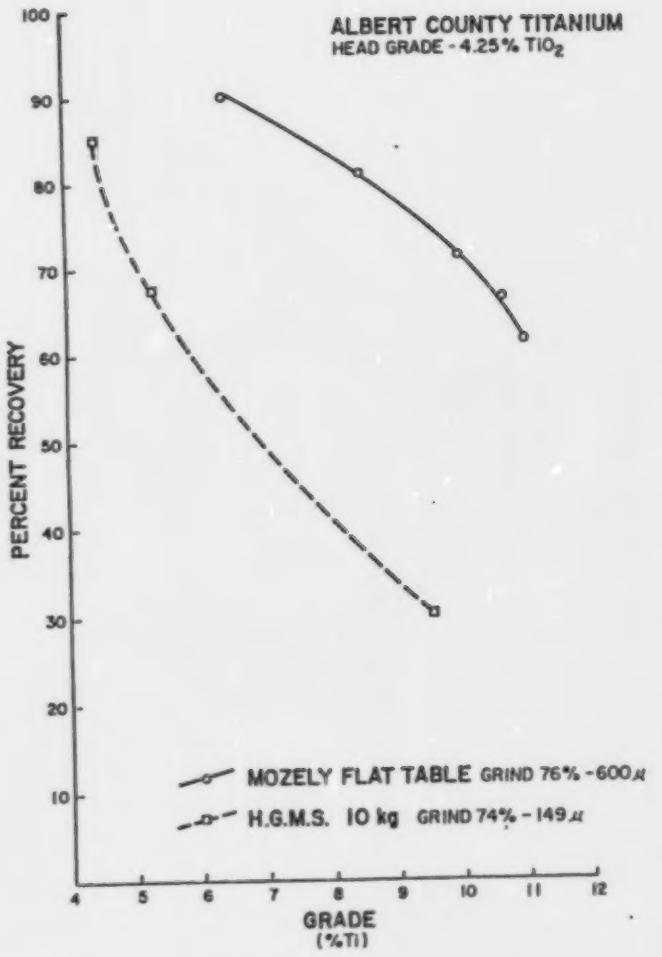
FIGURE 10: Flowsheet for the production of synthetic magnesium oxide from dolomite and sea water. Various developmental alternatives (flowsheet options) have been identified for yttrium-rare earth and phosphate recovery from apatite ore.

Separation tests have been done on the hardrock ilmenite deposit in Albert County, as shown in figure 11. The ore consists of very course grained ilmenite, with intimately associated hematite. Other similar deposits have used a combination of gravity concentrataion-magnetic-flotation flowsheets, where locked hematite-ilmenite fraction is removed magnetically and returned to the grinding section. The flowsheet of figure 11 will be bench-tested to determine if separation and upgrading can be achieved on this deposit.

Low concentrations of gallium and germanium have been found in the Albert County titanium (20-30ppm) and the Woodstock manganese (15-20ppm). Various leaching tests were conducted to examine the option of by-product production. Limited extractions did not prove this concept to be feasible.

Flowsheet Development (Tungsten and Complex Sulfides)

The flowsheet including gravity separation and sodium hydroxide hydrometallurgical methods to produce ammonium paratungstate (APT) is being reviewed, as shown in figure 12. The overall valve of the ore is approximately $28-35/t ore, based on the present price of APT. Although this value is not considered economic, the development of a flowsheet to produce APT is believed to be positive in anticipation of improved metal prices and the possibility of free trade with the United States.



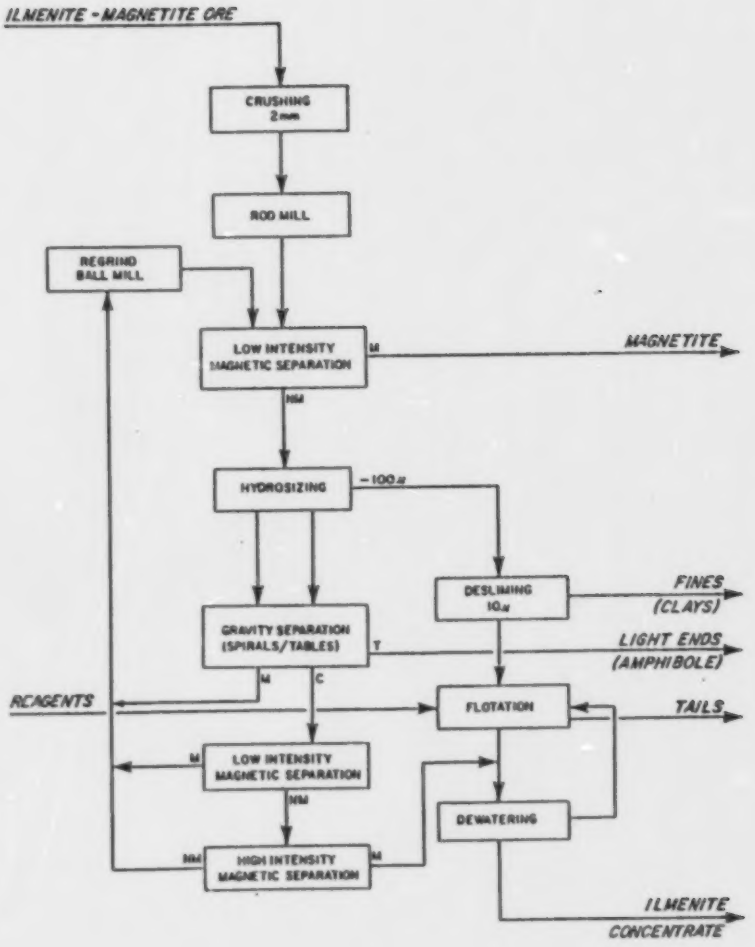


FIGURE 11: Ore separation tests done on core samples and mineralogy has led to the design of a conceptual flowsheet.

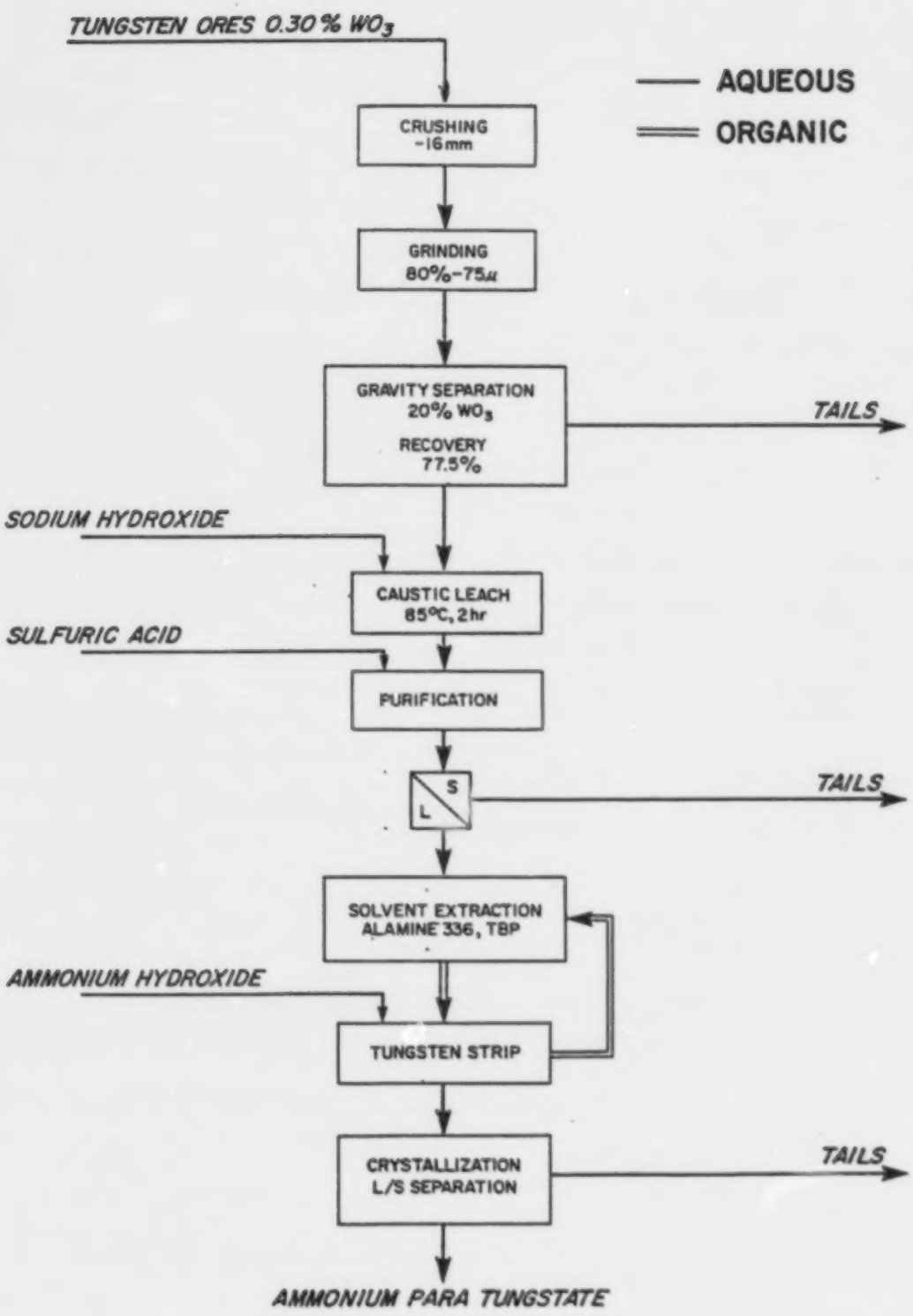


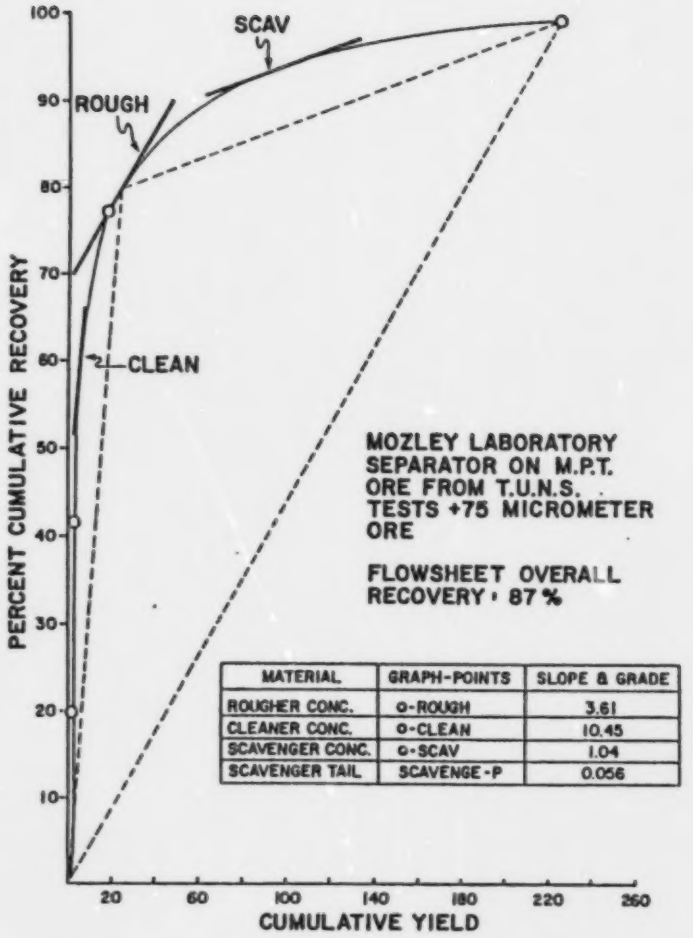
FIGURE 12: Flowsheet for the production of ammonium paratungstate from wolframite ores.

The liberation size (grind requirements) for wolframite, on a gravity circuit, has been determined to be about 80% -75u. The flowsheet for a gravity circuit has been designed, based on grade-recovery relationships of the ore and preliminary separation test done on table and spirals, as shown in figure 13. The gravity circuit has been designed to produced 20% WO_3 at a recovery of 76%. The major loss of wolframite has been attributed to fine loss, where recovery of fines (column flotation) may improve on recovery. Capital and operating cost of this gravity circuit is presently being studied.

As discussed earlier, the rare earths present in the ore are associated with fluorite, which may be a major revenue generator for the orebody. It is expected that fluorite flotation may lead to possible developments of fluorite and REO recovery circuits. The technical aspects of fluorite flotation are presently being reviewed.

The production of ammonium paratungstate, from gravity concentrates, has been introduced as a concept to treat dirty concentrates as opposed to magnetic separation and leaching of arsenic, phosphate, etc. from concentrates. The APT production route may lower in operating cost with added value to product. Further testing of the hydromet is presently being carried out.

The concept of bulk flotation for complex sulfides is presently being bench-tested and commissioning of a flotation column is being carried out at Durham Mines. The operation of the column is being optimized to improve on recovery of fines. Various bubble generators are being tested.



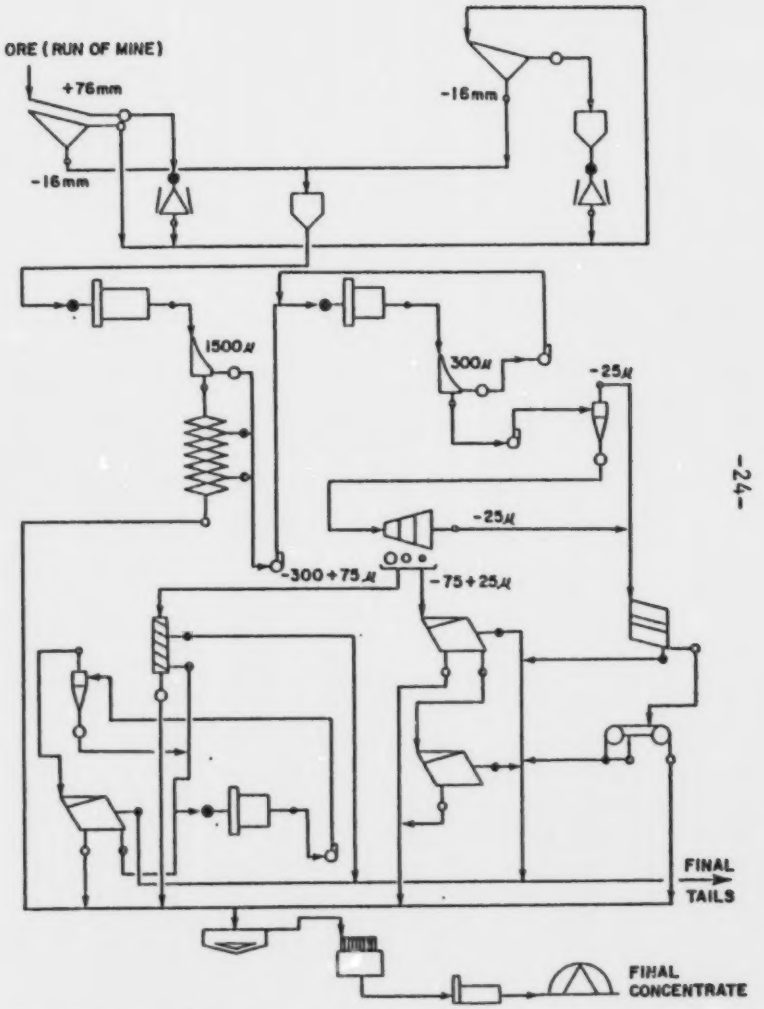


FIGURE 13: Grade-recovery testing on Mt. Pleasant ores has been used to design a conceptual flowsheet for the recovery of wolframite.

Mineral Investment Stimulation Program

Various projects are being carried out, under the MISP, relating to process development and extension of reserves. To date, twenty-two applications for assistance under the MISP have been received, of which fourteen have been approved. Some of the MISP projects have resulted from studies carried out under the MPIP. The following projects have been funded by MISP:

Antimony Float Study, Durham Resources Inc.

Project investigated the problems explaining the consistently low (85%) recovery of antimony at the plant's concentrator. The work entailed bench flotation tests under varying reagent concentration and type, size analysis on feed stock and product streams to determine metal (antimony) distribution and microscopic work to evaluate the characteristics of flotable and non-flotable antimony bearing minerals.

The was project was successful in characterizing the nature of the antimony losses to tailings and in providing some direction for modest improvement of the circuit.

Antimony Smelting Study, Durham Resources Inc.

Project consisted of a series of smelting tests for the purpose of assessing the feasibility of producing antimony metal from a sulphide concentrate. Various fluxes and reductants were tested.

The project was successful in producing antimony metal from concentrate under various conditions but was not very successful in achieving suitable recoveries.

Mineral Liberation Investigation, Brunswick Mining

Project will encompass a comprehensive mineralogical survey with the objective of determining the distribution of free and unliberated mineral grains within BMS' concentrator. Tests will include grain size analysis and mineral chemistry determinations of samples taken at various stages in the processing circuit.

Metal Distribution Study, Brunswick Mining

Project is aimed at determining the distribution of metals and trace elements within the concentrator at BMS. The work required the collection, size analysis and chemical analysis of various samples taken from the grinding, classification and flotation circuits of the concentrator.

Pyrite Flotation Tests, Brunswick Mining

Project investigated the technical feasibility of producing a marketable pyrite concentrate on a pilot scale. The work consisted of pyrite classification and flotation experiments.

Pressure Filtration Evaluation, Brunswick Mining

Project evaluated the effectiveness of a verti-press pressure filter on the dewatering of base metal concentrates. The work operated on a pilot scale and utilized feedstock composed of a lead concentrate. The parameters considered were production rate, air consumption, product moisture and cycle time.

Flash Flotation Study, Durham Resources Inc.

Project studied the effectiveness of flash flotation on the recovery of antimony minerals (mainly stibnite) and on the reduction of slime loss due to overgrinding of ore. The flash cell was installed in the grinding circuit as a way of attempting to recover coarse liberated antimony minerals.

Purification of Zinc Concentrates, Brunswick Mining

Project will assess the causes of zinc concentrate contamination and will evaluate the potential for improvement by column flotation. Activities will include column flotation experiments and mineralogical examinations of the process streams.

Further Characterization of Cape Spencer Gold Deposit, Mispec Resources Inc.

Project proposes to expand an established reserve of gold-bearing ore at Cape Spencer by diamond core drilling, trenching and assay analysis of the resulting samples for gold. The primary objectives are to further define and expand the gold zone known as the "Road Zone" and to ascertain the grade of the enriched surficial expression of the same zone.

Further Characterization of Plymouth Mn Deposit, Maritime Resource Inc.

Project will entail the further characterization of the established Plymouth Mn deposit near Woodstock, N. B. by trenching and diamond core drilling at selected sites and by detailed analysis of the resulting core samples for determining the content of Mn and other potentially economic minerals.

Gold Assessment at Lake George, Dominion Explorers

Project will assess the magnitude of a gold showing at the 850 ft level of the existing antimony mine at Lake George. The proposed work includes 500 feet of drifting with sampling at various intervals in effort to determine the width and length of auriferous sulphides in the fractured zones separate and north of the main antimony vein.

Reserves Extension of Antimony-Part 1, Dominion Explorers

Project will try to prove up additional adjoining reserves for the already producing antimony mine at Lake George by diamond drill testing for quartz/antimony veins that may exist in the untested area south of the main east-west producing vein. It is planned that 11,000 ft of diamond drilling will be done along a 12 mile picket line grid. The resulting core samples will be analyzed for antimony content.

Reserves Extension of Antimony-Part 2, Dominion Explorers

Project will try to prove up additional adjoining reserves for the already producing antimony mine at Lake George by diamond drill testing of various structures in the area of the Lawrence vein (discovered in the 1920's) approximately 4000' west of the main shaft. This investigation will also test some north-south trending geochemical anomalies. It is planned that 12,000 ft of drilling will be done along a 13 mile picket line grid. The resulting core samples will be analyzed for antimony content.

Survey of New Brunswick Gypsum, Eastern Gypsum Ltd.

Project will attempt to locate and characterize a viable in-province gypsum deposit as feedstock for a wallboard plant. As part of the study, the ores of various known gypsum deposits around the province will be sampled and tested for their suitability in making wallboard.

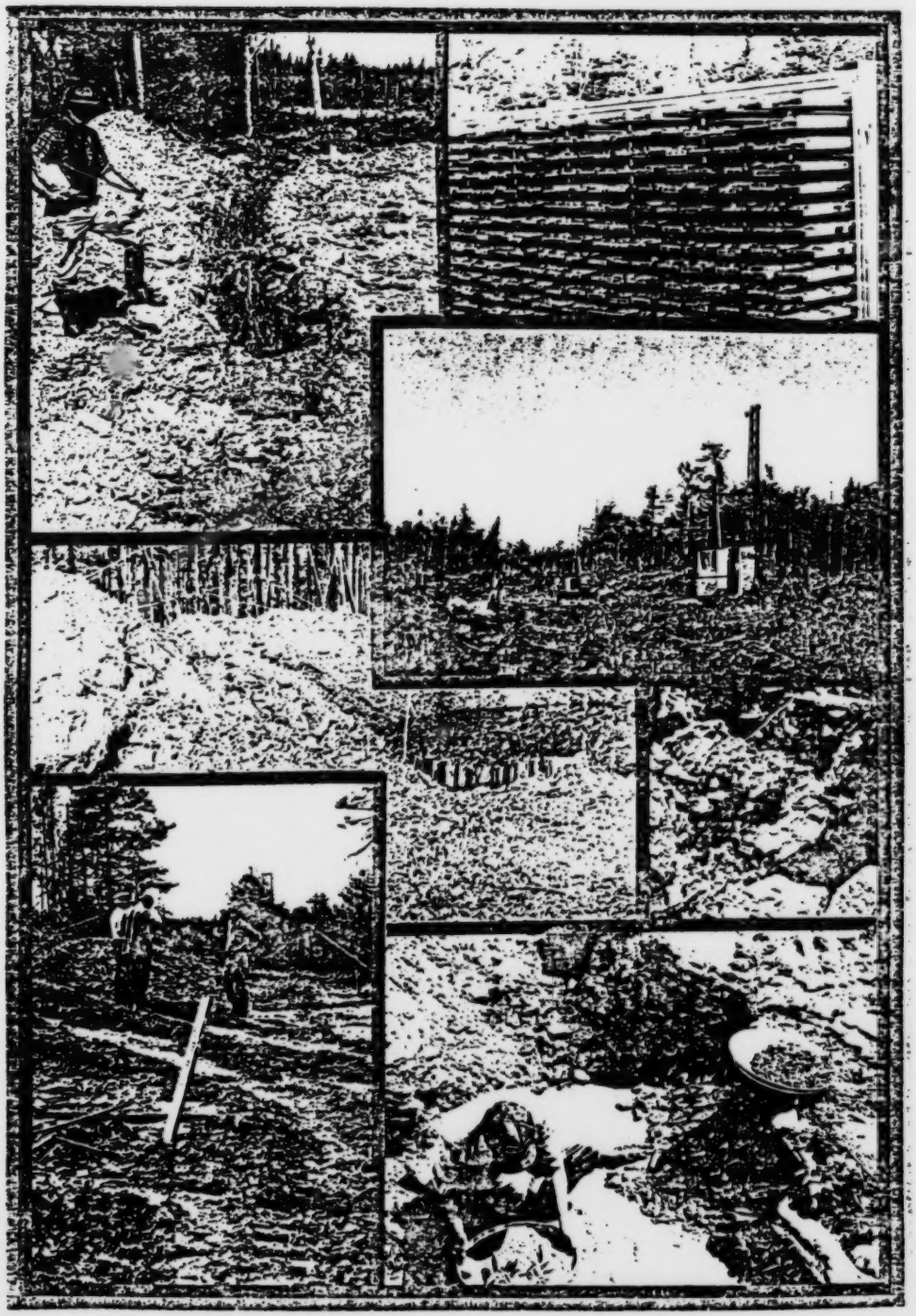


FIGURE 14: Geological Investigation of the Cape Spencer Gold Deposit by Mispec Resources Inc. This work was funded under the Mineral Investment Stimulation Program.

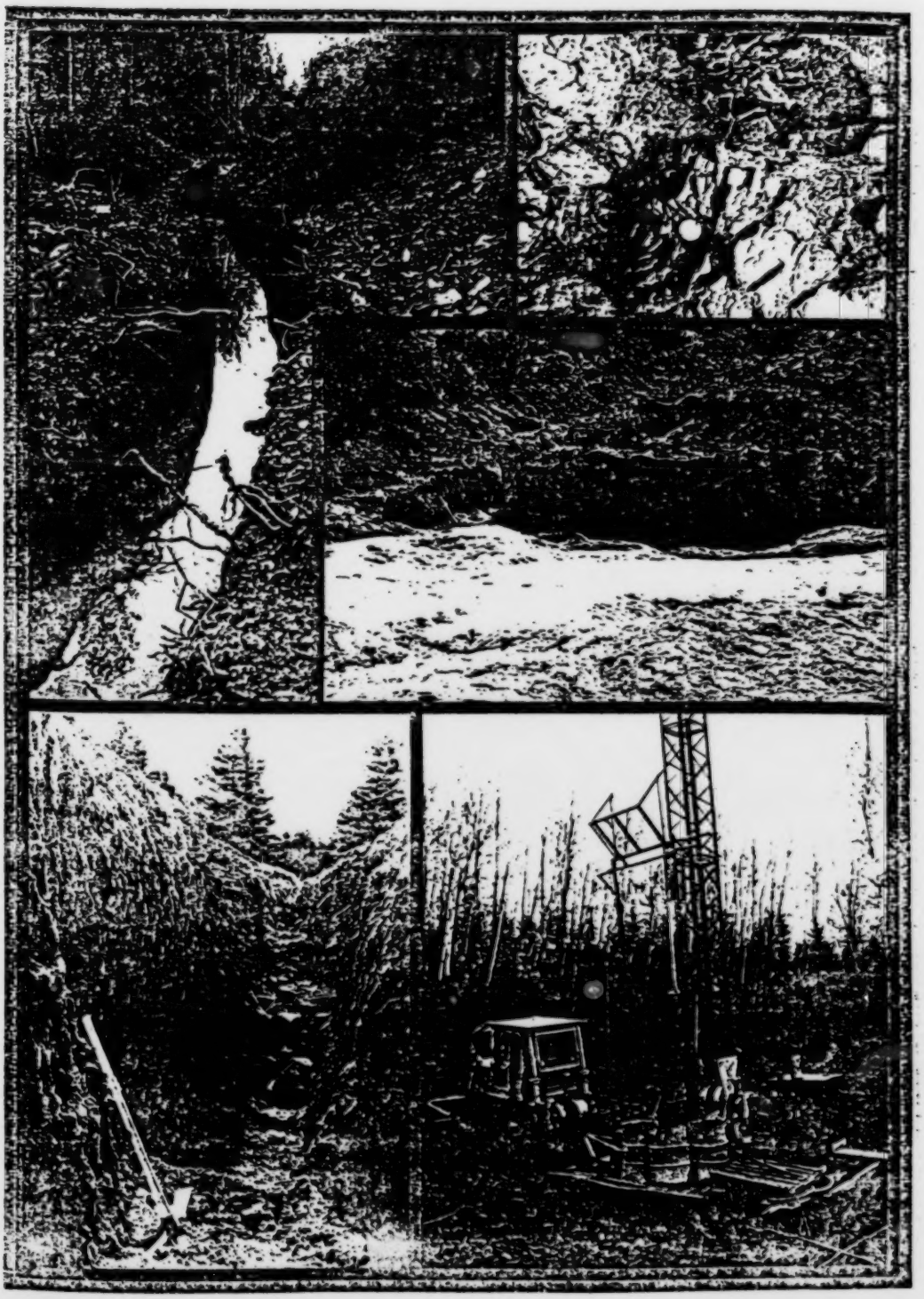


FIGURE 15: Geological Investigation of the Plymouth Manganese Deposit by Maritime Resource Research Ltd. This work was funded under the Mineral Investment Stimulation Program.

MINERAL PROCESSING INVESTIGATION PROGRAM (Federal Monies)

FINANCIAL REPORT (Second Quarter 87-88)

	Budget March 31/88	Committed Sept. 30/88	Balance To Sept. 30/87
Program Administration	$ 60,000	$ 25,741.63	$34,258.37
Benef. of Complex Sulfides	10,000	4,095.04	5,904.96
Process Dev. Of Mt. Pleasant	15,000	9,696.30	5,303.70
Processing of Sp. Metals	15,000	11,916.05	3,083.95
Cash Position	100,000	51,449.02	48,550.98

MINERAL INVESTMENT STIMULATION PROGRAM (Federal Monies)

FINANCIAL REPORT (Second Quarter 87-88)

	Project Budget	Budget To March 31/88	Committed Sept. 30/87	Balance To Sept. 30/87
Program ADM. (Year 2)	45,000	45,000	25,826	19,174
BMS-liberation	35,000			
BMS-metal dist.	21,000	(carried over to 88/89)		
BMS-Pyrite float	11,795	(carried over to 88/89)		
BMS-Press. Filter	14,508	(carried over to 88/89)		
Durham-flash float	11,620	(carried over to 88/89)		
BMS-column float	10,200		10,200	0
Maritime R.R.-Woodstock Mn.	50,000		15,000	35,000
MISPEC-Cape Spencer Au	50,000		30,000	20,000
Durham Gold-Lake George	50,000		15,000	35,000
Durham Antimony veins-Lake George (1)	50,000		15,000	35,000
Durham Antimony veins-Lake George (2)	50,000		15,000	35,000
Gypsum-Eastern Gypsum	30,000		0	30,000
Cash Position	394,123	400,000	126,026	273,974